

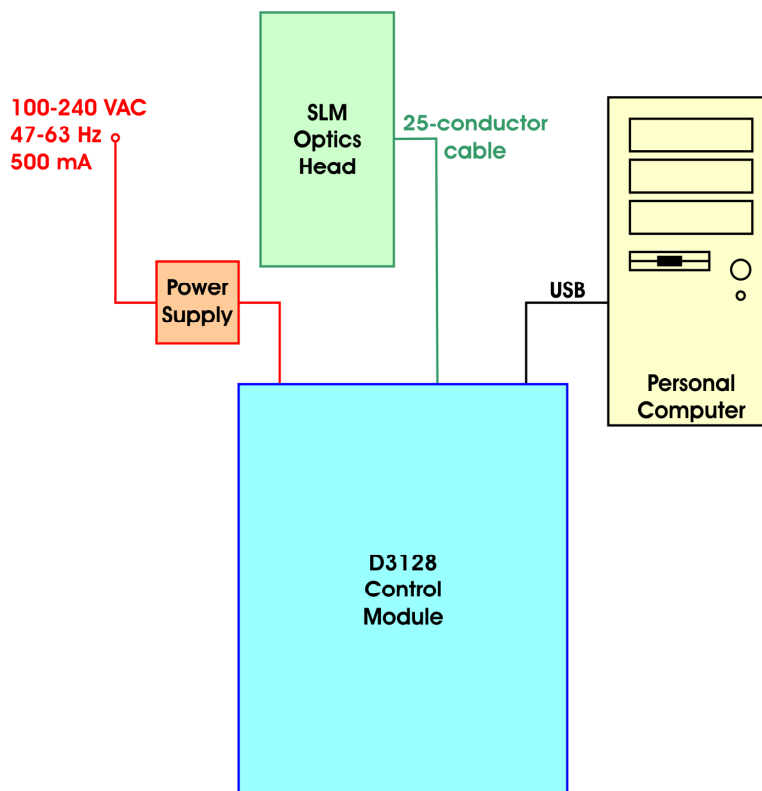


D3128 Spatial Light Modulator User's Manual

Revision 1.04

D3128 Spatial Light Modulator Quick Setup Guide

1. Install the PixelDRIVE 3000 software on a PC running Microsoft® Windows® (98SE or later). Place the included CD in the CD-ROM drive. Wait for the PixelDRIVE menu to appear, then click on the “Install PixelDRIVE ...” button.
2. Connect the D3128 control module (USB connector) to a PC (USB port) using the included USB cable.
3. With the SLM optics head positioned as desired, connect the optics head to the control module using the included 25-pin cable.
4. Plug the power supply cable into the power connector on the D3128 control module. Connect the power supply to a properly grounded outlet.
5. If array updates are to be synchronized to other experiment equipment, connect the TRIGGER output SMB terminal to the high-impedance trigger input of other laboratory devices.
6. Power on the D3128 control module. The POWER light will illuminate and the STATUS light will blink the firmware version during initialization. After initialization, the STATUS light will go off. The POWER light remains illuminated until the power is turned off.
7. The first time the unit is powered on, Windows® will detect new hardware and prompt for a driver. The driver files are on the PixelDRIVE 3000 CD. For Windows® 2000 and Windows® XP, drivers are in the USB DRIVERS\WIN2K_XP directory. The drivers for Windows® 98SE and Windows® ME are in the USB DRIVERS\WIN98_ME directory.
8. Start the PixelDRIVE 3000 software by clicking Start|Programs|Meadowlark Optics|PixelDRIVE 3000.



D3128 Spatial Light Modulator

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D3128 Spatial Light Modulator

The D3128 from Meadowlark Optics, Inc. is a complete liquid crystal spatial light modulator solution. The optical head includes the LC pixel array, configured in either a 128-pixel linear or 127-pixel hexagonal geometry. The LC is thermally stabilized by two independent temperature feedback control sub-circuits. The optical head mounts in a laboratory setup using standard ¼-20 or 8-32 hardware, and it electrically connects to a compact control module by one convenient 25-pin cable. The control module includes an output trigger channel for integrating the SLM with other laboratory equipment, and connects easily to a PC with a USB cable. The software provides control of individual pixels as well as functions that treat the array as a whole, dual-channel temperature control, multiple frame configuration, timing control, and file I/O, all through an attractive, user-friendly interface. The CD includes LabVIEW™ development resources for customers wishing to design control features using National Instruments LabVIEW™.

1. Nematic Liquid Crystal Technology: The Basics

1.1 Nematic LCVR Physical Architecture

Typical nematic Liquid Crystal Variable Retarders (LCVRs) such as the LVR- and LRC- series by Meadowlark Optics are constructed using optically flat fused silica windows coated with transparent conductive indium tin oxide (ITO). A thin dielectric layer is applied over the ITO and gently rubbed, creating parallel micro-grooves for liquid crystal molecular alignment. Two windows are then carefully aligned and spaced a few microns apart. The cavity is filled with birefringent nematic liquid crystal material. Electrical contacts are attached and the device is environmentally sealed.

Anisotropic nematic liquid crystal molecules form uniaxial birefringent layers in the liquid crystal cell. An essential feature of nematic material is that, on average, molecules are aligned with their long axes parallel, but with their centers randomly distributed, as shown in Fig. 1. With no voltage applied, the liquid crystal molecules lie parallel to the glass substrates and maximum retardation is achieved.

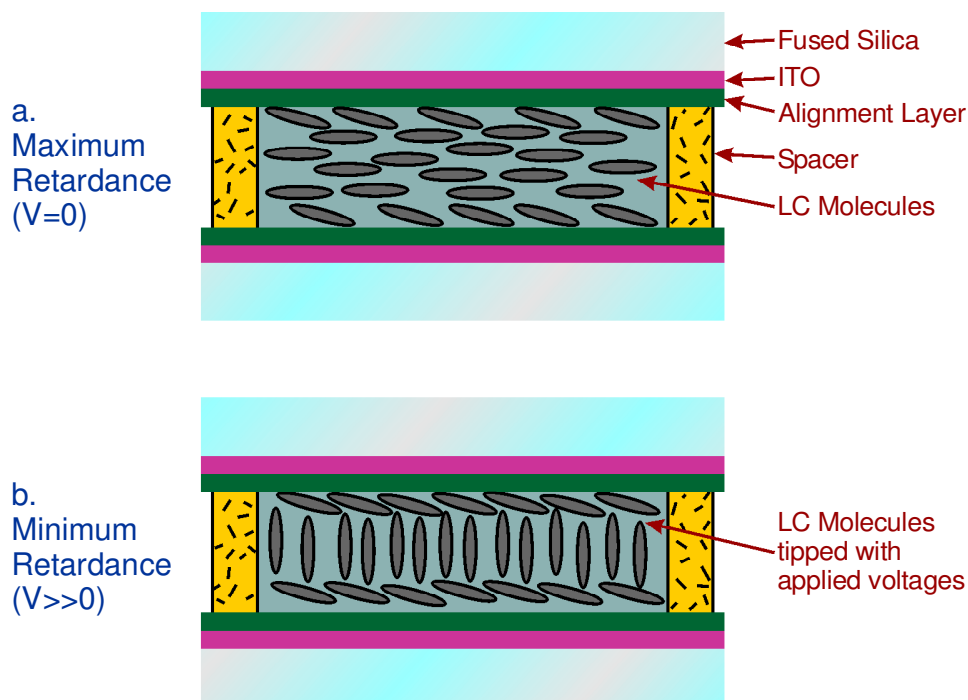


Figure 1. Liquid Crystal Variable Retarder construction showing molecular alignment (a) without and (b) with applied voltage (drawing not to scale)

When voltage is applied, liquid crystal molecules begin to tip perpendicular to the fused silica windows. As voltage increases, molecules tip further causing a reduction in the effective birefringence and hence, retardance. Molecules at the surface, however, are unable to rotate freely because they are pinned at the alignment layer. This surface pinning causes a residual retardance of ~30 nm even at high voltage (20 volts). We achieve zero (or any custom) retardance with a subtractive fixed polymer retarder, called a compensator, attached to the liquid crystal cell. Negative retardance values are sometimes preferred for example, when converting between right- and left-circularly polarized states. Fig. 2 illustrates retardance as a function of voltage for a typical LCVR with and without an attached compensator. Placing a compensated LCVR between two high extinction polarizers creates an excellent optical attenuator, with convenient electronic control.

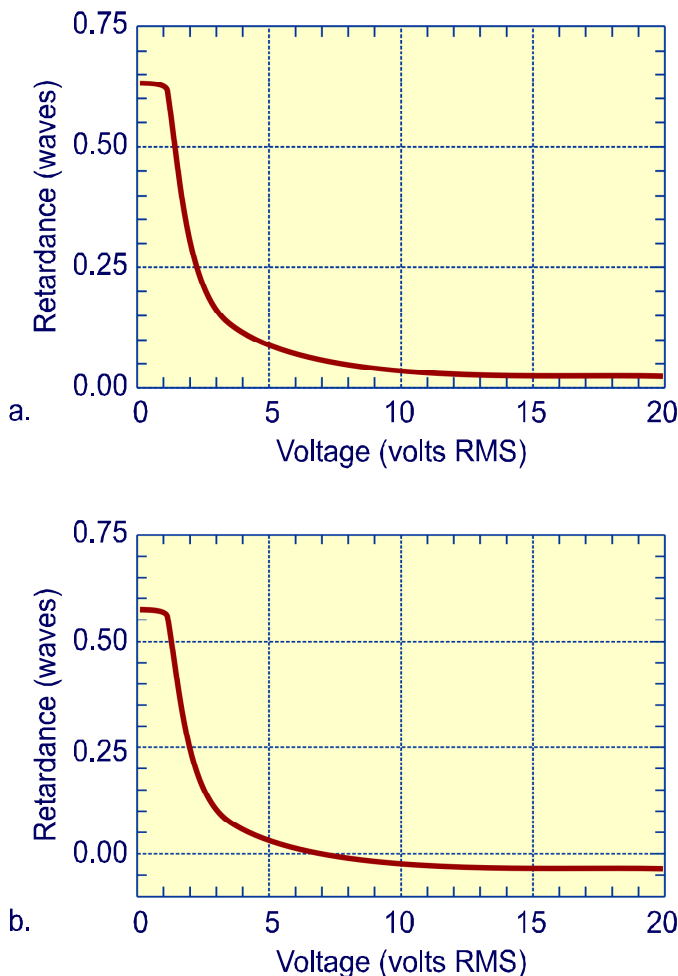


Figure 2. Liquid Crystal Variable Retarder performance at 632.8 nm, 21°C (a) without compensator, and (b) with compensator

As with any birefringent material, retardance is dependent upon thickness and birefringence. Liquid crystal material birefringence depends on operating wavelength, drive voltage, and temperature. The overall retardance of a liquid crystal cell decreases with increasing temperature (approximately -0.4% per °C).

Liquid crystal devices should be electrically driven with an AC waveform with no DC components to prevent ionic buildup which can damage the liquid crystal layer. LCVR's from Meadowlark Optics for instance require a 2 kHz square wave with a zero-average voltage. Retardance is controlled by varying the peak-to-peak voltage from zero to $\pm 10V$.

1.2 Building a Liquid Crystal Pixel Array

The conductive ITO layers of a typical LC cell are uniform so that an applied square-wave voltage signal establishes a uniform electric field throughout the LC-filled region of the cell. With a spatial light modulator, the conductive ITO on one piece of glass is etched into a pattern much like the copper layer of a printed circuit board is etched into a pattern that is useful for the desired circuit design. The ITO on the other piece of glass is uniform to provide a common ground. The etched piece has ITO in the desired pixel pattern, and traces that electrically connect each pixel to the edge of the glass. The SLM LC cell is assembled and filled in the same manner as a variable retarder. A unique type of multi-conductor cable adheres to the glass and electrically connects the array of pixel connectors to the circuit that drives them.

2. Hardware Setup and Configuration

2.1 Laboratory and System Requirements for the D3128

- 100-240 VAC, 47-63 Hz 500 mA utility power.
- A PC with an available USB port.
- Minimum PC requirements to run the included PixelDRIVE 3000 software are a Pentium® processor, 64 MB RAM, 20 MB hard drive space, 800x600 pixel, 16-bit color graphics, a CD-ROM, and Microsoft® Windows® 98SE, ME, 2000 or XP.
- Recommended PC specifications are a 1-GHz Pentium® III processor, 256 MB RAM, 20 MB hard drive space, 1024x768 pixel, 16-bit color graphics, a CD-ROM, and Microsoft® Windows® 2000 or XP.

2.2 Setup Procedure for the D3128

1. Unpack controller and cables from shipping container. Please verify that your shipment included:
 - D3128 controller unit (1)
 - SLM optical head unit (1)
 - 25-conductor optical head cable (1)
 - +12V power supply and power cable (1 unit with +12V cable attached and 1 AC power cable)
 - USB cable (1)
 - PixelDRIVE 3000 software CD (1)
 - User's manual (1 printed copy)
2. Hardware configuration of the D3128 control module:
 - Position the SLM optical head securely on an optics table or breadboard. The optical head has two 8-32 tapped holes on all four edges, as well as ¼-20 tapped holes on two edges for mounting the SLM optical head with standard optics hardware.
 - Connect the 25-pin optical head cable to the optical head. The optical head connector is keyed to disallow improper insertion. Connect the other end of the optical head connector to the D3128 control module.
 - Connect the +12VDC supply to the D3128 control module. Plug the power supply into a properly grounded AC outlet.
 - Attach the USB cable to the USB connector on the rear of the D3128 control module, and connect the other end to an available USB port on a PC.
 - If synchronizing array updates to other experiment equipment, connect the TRIGGER output SMB terminal to the high-impedance trigger input of other laboratory devices.

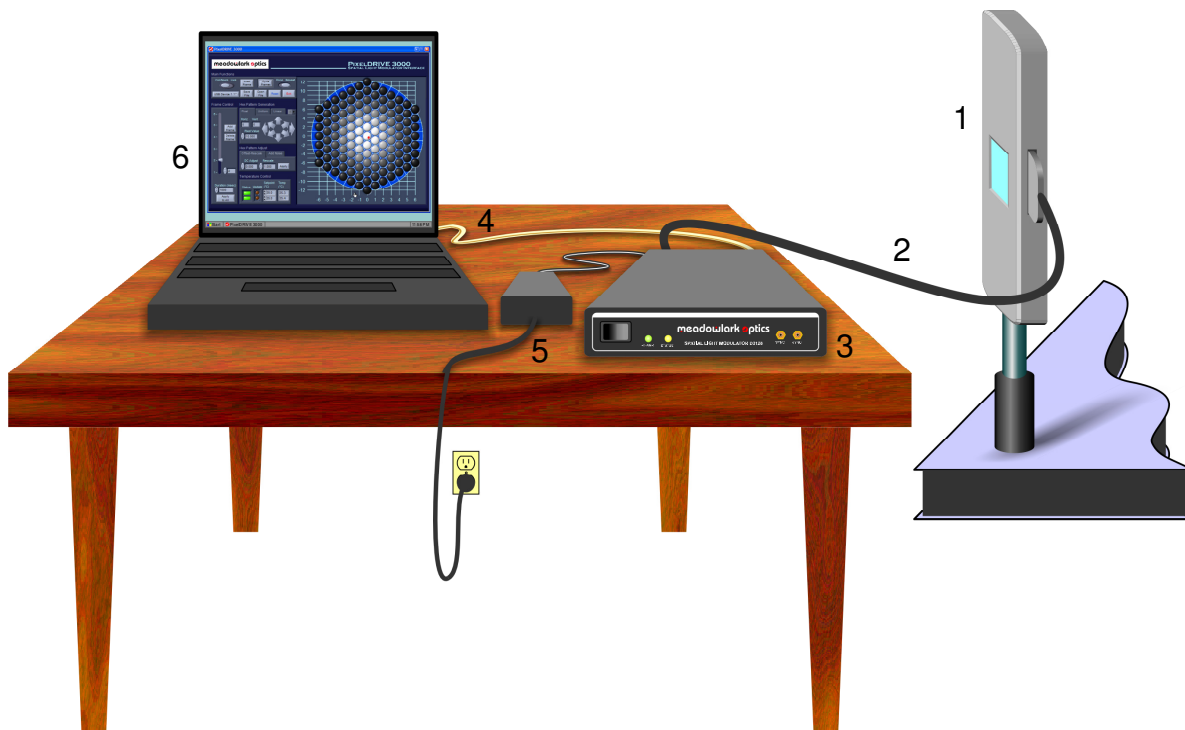


Figure 3. Spatial Light Modulator Components. (1) SLM optical head, (2) Optical head cable, (3) D3128 Controller, (4) USB cable, (5) Power supply, (6) PC running PixelDRIVE 3000.

3. Turn on the front panel switch and observe the LED's. The green power LED remains illuminated as long as the unit is powered on. The yellow status LED blinks the D3128's firmware version as the D3128 control module performs a power-on self-test, then goes off. During the power-on self-test, the entire pixel array will be driven to maximum voltage for 500 ms, reduced to half-voltage for 500 ms, then reduced to zero upon completion of the power-on self-test.
4. The first time the D3128 is powered on, Windows® will detect a new USB device upon completion of the power-on self-test. For installation to a PC running Windows® 2000, Windows® XP or Windows Vista®, direct Windows® to look in the USB Drivers\Win2K_XP directory on the CD. For installation to a PC running Windows® 98SE or Windows® ME, specify the USB Drivers\Win98_ME directory. Note: Windows® may say that the driver has not passed certification; press continue anyway. The drivers have been extensively tested.
5. Install the PixelDRIVE 3000 software by first placing the PixelDRIVE CD in the CD-ROM drive. Then, wait for the PixelDRIVE menu to appear and click on the "Install PixelDRIVE ..." button. If the menu does not appear, go to "My Computer" or Windows Explorer, double click on the CD-ROM drive, and double click on Autorun.exe in the Autorun directory.

3. Hexagonal 127-Pixel Array

Two available D3128 optical configurations are the 127-pixel hexagonal array and the 128-pixel linear array. Both optical configurations include software that has been customized to the geometry of the pixel array. The software that drives the hexagonal array is detailed here; please refer to Section 4 for a discussion of the software that drives the linear array.

3.1 PixelDRIVE 3000 Software for the Hexagonal Array

The D3128 includes PixelDRIVE 3000: a user-friendly software interface for control of the spatial light modulator. Here we detail the functions of PixelDRIVE 3000. Also included on the CD are LabVIEW™ VI's

(compatible with National Instruments LabVIEW™ versions 6.1 or later) that end users can include in their own development efforts.



Voltage levels here refer to the amplitude envelope about a 2 kHz square wave with zero DC offset. Never apply a voltage with a non-zero DC component to a liquid crystal cell.

As voltage levels are mentioned in the present context, it is important to bear in mind that we are describing the amplitude envelope about a 2-kHz square wave. For instance, a driver signal described as “invariant” actually refers to a square wave with a steady amplitude; the envelope is unchanging in time but the signal itself (if measured with an oscilloscope for instance) oscillates about the zero-voltage axis. It is important to note that the square wave is always symmetric about the zero-voltage axis. As previously mentioned, zero-offset is critical for nematic liquid crystal cells.

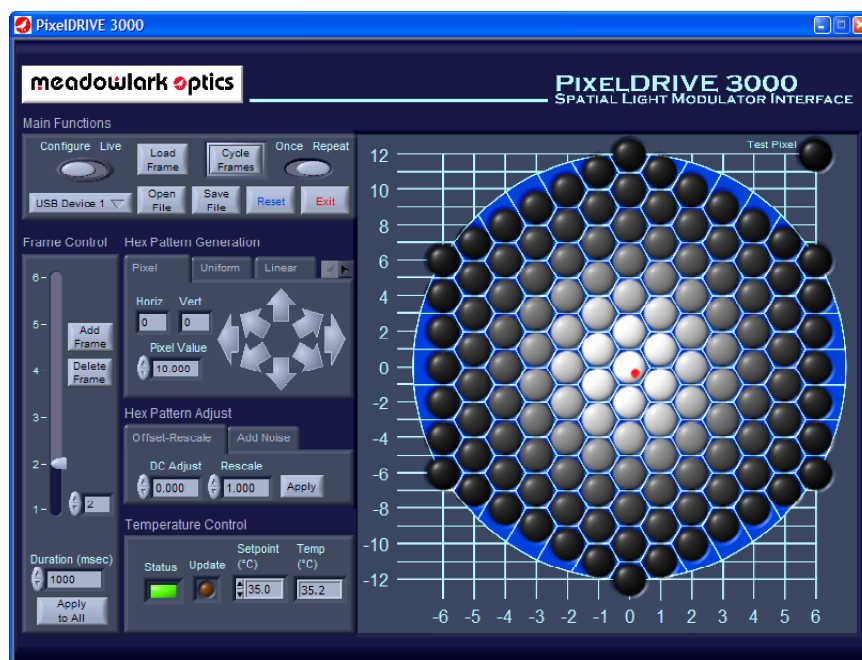


Figure 4. PixelDRIVE 3000 (Hex) User Interface

PixelDRIVE 3000 provides an easily accessible user interface by which to control the pixels of the spatial light modulator. The software grants control of the pixel array through manipulation of the individual pixels and through spatial functions that can be applied to the pixel array as a whole. Multiple arrays, called frames, can be configured independently of one another. A sequence of frames can be cycled, and the duration of each frame can be specified. The software also enables temperature control and monitoring.

From here, the user interface will be considered in six sections, shown in Fig. 5. In addition to the controls and indicators within the six sections highlighted in Fig. 5, clicking the Meadowlark Optics logo displays software and firmware version information.

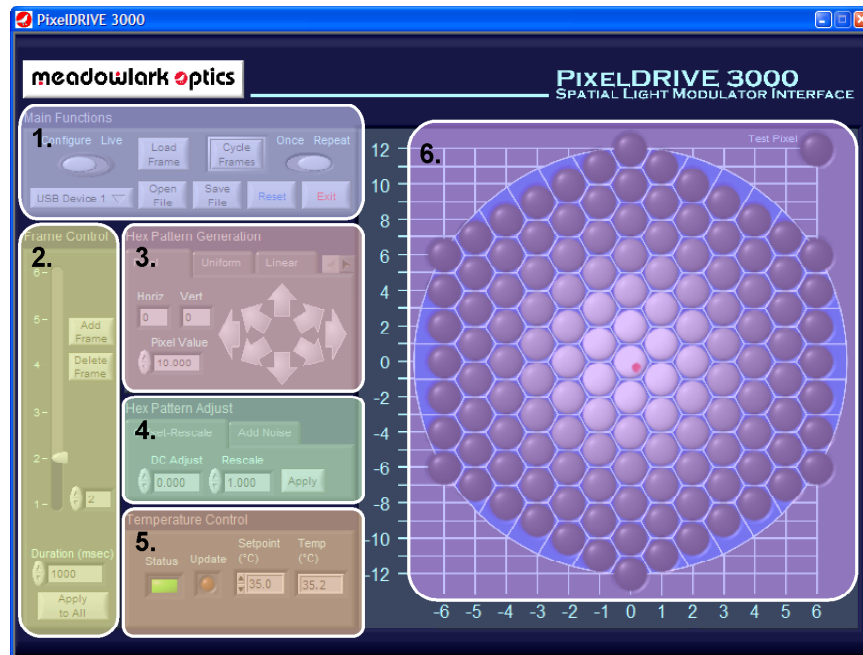


Figure 5. Sectioned PixelDRIVE 3000 (Hex) Interface. (1) Main functions, (2) Frame control, (3) Hex pattern generation, (4) Hex pattern adjustment, (5) Temperature control, (6) Pixel control/display.

3.1.1 Main Functions

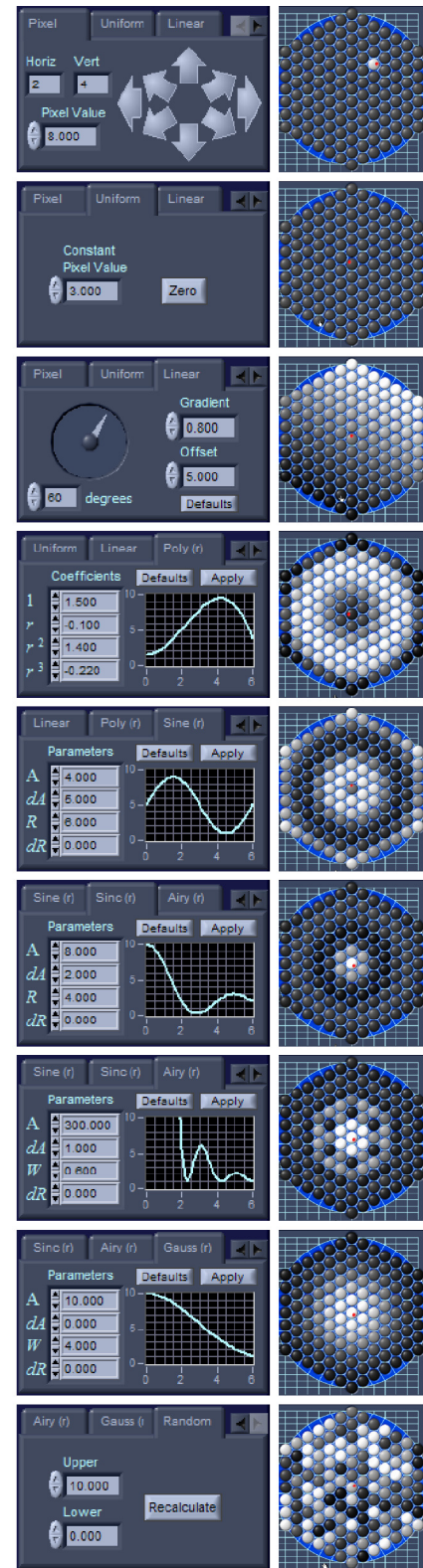
- **CONFIGURE/LIVE** In LIVE mode, changes made to the on-screen pixel array are immediately relayed to the SLM hardware. In the CONFIGURE mode, changes will not be updated until either LOAD FRAME or CYCLE FRAMES is pressed.
- **LOAD FRAME** Loads the current on-screen pixel array to the SLM hardware.
- **CYCLE FRAMES** Activates frame cycling, loading each frame in sequence to the SLM hardware for the specified duration. When frame cycling is activated, a small window replaces the main user interface indicating cycling progress and allowing the user to cease frame cycling.
- **ONCE/REPEAT** Controls whether the CYCLE FRAMES control will load the frame sequence only once, or repeat the sequence until the user deactivates frame cycling.
- **USB DEVICE #** Selects among several Meadowlark Optics USB devices when several Meadowlark Optics USB devices are connected to the PC.
- **OPEN FILE** Reads frame and pixel array configuration data from an ASCII text file (see Appendix A for the file specification).
- **SAVE FILE** Writes the current frame and pixel array configuration to an ASCII text file (see Appendix A for the file specification).
- **RESET** Performs a soft reboot of the D3128 controller and re-enumerates the USB connection.
- **EXIT** Quit PixelDRIVE 3000.

3.1.2 Frame Control

- **FRAME SELECTOR (slider and numeric control)** Selects a pixel array from the sequence and renders it on the display.
- **ADD FRAME** Adds a new frame to the sequence after the current frame.
- **DELETE FRAME** Removes the current frame from the sequence.
- **DURATION (MSEC)** Specifies the duration time in milliseconds of the current frame.
- **APPLY TO ALL** Sets the duration time of all frames to that of the current frame.

3.1.3 Hex Frame Generation

- **PIXEL** Use the arrows or enter horizontal and vertical pixel indices to change the selected pixel. Change the pixel value to the desired level. *Hint:* The horizontal and vertical indices must both be either odd or even, i.e., (0,0) and (1,1) are valid but (0,1) is not valid.
- **UNIFORM** Sets each pixel in the array to a uniform value.
- **LINEAR** Applies a linear gradient across the pixel array. The angle specifies the direction of the gradient, the gradient value specifies the spatial rate of variation across the array, and the offset uniformly adjusts the pixel values.
- **POLY (r)** Applies a radially-symmetric polynomial function, up to third-order. The r^0 , r^1 , r^2 , and r^3 coefficients can be entered. A small plot of pixel value vs. r is displayed.
- **SINE (r)** Applies a radially-symmetric sinusoidal function. A is the 0-peak amplitude, dA is the pixel value offset, R is the radial period, and dR is the radial offset. A small plot of pixel value vs. r is displayed.
- **SINC (r)** Applies a radially-symmetric sinc $\{\sin(r)/r\}$ function. A is the 0-peak amplitude, dA is the pixel value offset, R is the radial period, and dR is the radial offset. A small plot of pixel value vs. r is displayed.
- **AIRY (r)** Applies a radially-symmetric Airy disk function. A is the peak amplitude, dA is the pixel value offset, W is the width, and dR is the radial offset. A small plot of pixel value vs. r is displayed.
- **GAUSS (r)** Applies a radially-symmetric Gaussian function. A is the peak amplitude, dA is the pixel value offset, W is the width, and dR is the radial offset. A small plot of pixel value vs. r is displayed.
- **RANDOM** Randomly calculates a value between the specified upper and lower limits for each pixel.



3.1.4 Hex Pattern Adjust

- **OFFSET-RESCALE**
 - **DC ADJUST** is a constant value to be added to each pixel.
 - **RESCALE** is a multiplier by which each pixel will be scaled.
 - **APPLY** rescales and offsets the pixel array.
- **ADD NOISE** Adds or subtracts a random value to each pixel.
 - **NEG LIMIT** The maximum value that would be subtracted from each pixel.
 - **POS LIMIT** The maximum value that would be added to each pixel.

3.1.5 Temperature Control

- **STATUS** LED illuminates green when the SLM temperature is within $\pm 1^\circ\text{C}$ of the setpoint.
- **UPDATE** LED blinks when the SLM temperature is measured.
- **SETPOINT ($^\circ\text{C}$)** Sets the desired operating temperature of the SLM.
- **TEMP ($^\circ\text{C}$)** Shows the current measured temperature of the SLM, updated automatically at ~ 2 sec intervals. *Note that automatic temperature measurement is disabled when frame cycling is active.*

3.1.6 On-Screen Pixel Array

- Shows the voltage settings of each pixel as a greyscale value; black corresponds to zero volts (maximum retardance) and white corresponds to ten volts (minimum retardance).
- Clicking a pixel highlights it as the “selected pixel” with a red dot; the angle of the red dot is indicative of the pixel value.
- Clicking and “rotating” a pixel varies its value.
- The “extra” pixel control at $(x, y) = (6, 12)$ of the on-screen pixel array controls the large test pixel.

3.2 The Indexing Convention of the Hexagonal Pixel Array

The on-screen pixel array locates pixels in the SLM by (x, y) coordinate indices. Fig. 7 shows the coordinate system, and illustrates the restriction that valid coordinate pairs must be (odd, odd) or (even, even). Fig. 6 shows highlighted pixels at $(x, y) = (0, 0)$ and at $(x, y) = (1, 3)$ as examples of valid pixel index coordinate pairs. A counterexample at $(x, y) = (3, 6)$ shows an invalid coordinate pair. Fig. 6 also shows the index limits of $-6 \leq x \leq 6$ and $-12 \leq y \leq 12$.

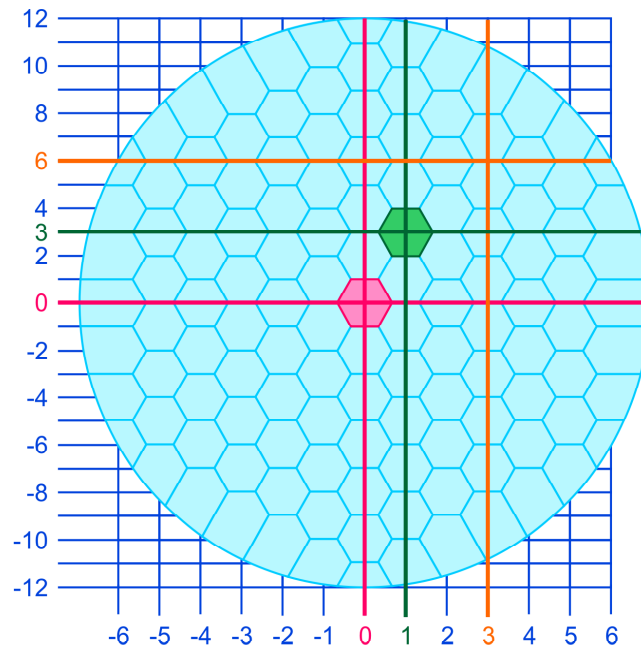


Figure 6. Hexagonal Pixel Array Indexing. Valid pixel coordinate indices are exemplified at $(x, y) = (0, 0)$ and $(1, 3)$, while an invalid pixel coordinate pair is exemplified at $(x, y) = (3, 6)$.

The pixel indexing convention results in a $\sqrt{3}:1$ geometric aspect ratio, as shown in Fig. 7. In order to adapt an analytical function of x and y , the y variables appearing in the analytical form must be divided by $\sqrt{3}$ (or x variables must be multiplied by $\sqrt{3}$) to achieve proper symmetric rendering on the pixel array.

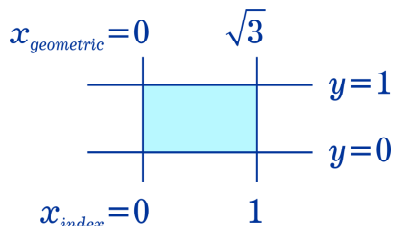


Figure 7. Pixel Indexing Aspect Ratio.

4. Linear 128-Pixel Array

Two available D3128 optical configurations are the 127-pixel hexagonal array and the 128-pixel linear array. Both optical configurations include software that has been customized to the geometry of the pixel array. The software that drives the linear array is detailed here; please refer to Section 3 for a discussion of the software that drives the linear array.

4.1 PixelDRIVE 3000 Software for the Linear Array

The D3128 includes PixelDRIVE 3000: a user-friendly software interface for control of the spatial light modulator. Here we detail the functions of PixelDRIVE 3000. Also included on the CD are LabVIEW™ VI's (compatible with National Instruments LabVIEW™ versions 6.1 or later) that end users can include in their own development efforts.



Voltage levels here refer to the amplitude envelope about a 2 kHz square wave with zero DC offset. Never apply a voltage with a non-zero DC component to a liquid crystal cell.

As voltage levels are mentioned in the present context, it is important to bear in mind that we are describing the amplitude envelope about a 2-kHz square wave. For instance, a driver signal described as “invariant” actually refers to a square wave with a steady amplitude; the envelope is unchanging in time but the signal itself (if measured with an oscilloscope for instance) oscillates about the zero-voltage axis. It is important to note that the square wave is always symmetric about the zero-voltage axis. As previously mentioned, zero-offset is critical for nematic liquid crystal cells.

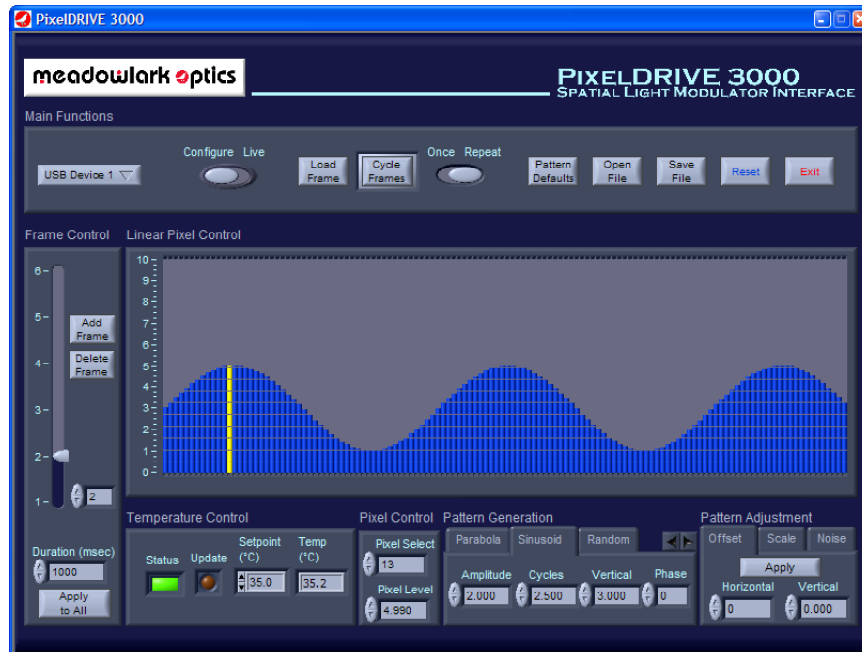


Figure 8. PixelDRIVE 3000 (Linear) User Interface

PixelDRIVE 3000 provides an easily accessible user interface by which to control the pixels of the spatial light modulator. The software grants control of the pixel array through manipulation of the individual pixels and through spatial functions that can be applied to the pixel array as a whole. Multiple arrays, called frames, can be configured independently of one another. A sequence of frames can be cycled, and the duration of each frame can be specified. The software also enables temperature control and monitoring.

From here, the user interface will be considered in seven sections, shown in Fig. 9. In addition to the controls and indicators within the six sections highlighted in Fig. 9, clicking the Meadowlark Optics logo displays software and firmware version information.



Figure 9. Sectioned PixelDRIVE 3000 (Linear) Interface. (1) Main functions, (2) Frame control, (3) Pixel control/display, (4) Temperature control, (5) Single-pixel select/control, (6) Linear pattern generation, (7) Linear pattern adjustment.

4.1.1 Main Functions

- **USB DEVICE #** Selects among several Meadowlark Optics USB devices when several Meadowlark Optics USB devices are connected to the PC.
- **CONFIGURE/LIVE** In LIVE mode, changes made to the on-screen pixel array are immediately relayed to the SLM hardware. In the CONFIGURE mode, changes will not be updated until either LOAD FRAME or CYCLE FRAMES is pressed.
- **LOAD FRAME** Loads the current on-screen pixel array to the SLM hardware.
- **CYCLE FRAMES** Activates frame cycling, loading each frame in sequence to the SLM hardware for the specified duration. When frame cycling is activated, a small window replaces the main user interface indicating cycling progress and allowing the user to cease frame cycling.
- **ONCE/REPEAT** Controls whether the CYCLE FRAMES control will load the frame sequence only once, or repeat the sequence until the user deactivates frame cycling.
- **PATTERN DEFAULTS** Resets the default values for the selected pixel pattern (see Section 4.1.6 for a discussion of pattern generation).
- **OPEN FILE** Reads frame and pixel array configuration data from an ASCII text file (see Appendix A for the file specification).
- **SAVE FILE** Writes the current frame and pixel array configuration to an ASCII text file (see Appendix A for the file specification).
- **RESET** Performs a soft reboot of the D3128 controller and re-enumerates the USB connection.
- **EXIT** Quit PixelDRIVE 3000.

4.1.2 Frame Control

- **FRAME SELECTOR (slider and numeric control)** Selects a pixel array from the sequence and renders it on the display.
- **ADD FRAME** Adds a new frame to the sequence after the current frame.
- **DELETE FRAME** Removes the current frame from the sequence.
- **DURATION (MSEC)** Specifies the duration time in milliseconds of the current frame.
- **APPLY TO ALL** Sets the duration time of all frames to that of the current frame.

4.1.3 On-Screen Pixel Array

- Shows graphically the voltage settings of each pixel (vertical) vs. the pixel index number (horizontal).
- Clicking a pixel highlights it yellow as the “selected pixel”.
- Clicking and “sliding” a pixel vertically varies its value.

4.1.4 Temperature Control

- **STATUS** LED illuminates green when the SLM temperature is within $\pm 1^{\circ}\text{C}$ of the setpoint.
- **UPDATE** LED blinks when the SLM temperature is measured.
- **SETPOINT ($^{\circ}\text{C}$)** Sets the desired operating temperature of the SLM.
- **TEMP ($^{\circ}\text{C}$)** Shows the current measured temperature of the SLM, updated automatically at ~5 sec intervals. *Note that automatic temperature measurement is disabled when frame cycling is active.*

4.1.5 Single-Pixel Select/Control

- Includes pixel select and pixel level controls to precisely set the voltage of a specific pixel.
- The selected pixel is highlighted yellow in the On-Screen Pixel Array
- Changes to the voltage will be rendered in the On-Screen Pixel Array.
- Selecting or changing the voltage of a pixel by clicking the On-Screen Pixel Array will update these controls.

4.1.6 Pattern Generation

- **CONSTANT** Sets each pixel in the array to a uniform value
- **LINEAR** The voltages will vary linearly across the array from the voltage of pixel 1 to the voltage of pixel 128.
- **PARABOLA** Varies the voltage quadratically across the array.
 - **NEG/POS** Specifies whether the parabolic voltage function will open “down” or “up”.
 - **MAGNITUDE** Scales the parabolic voltage function.
 - **HORIZONTAL** Shifts the parabolic voltage function left or right.
 - **VERTICAL** Applies a DC offset to the parabolic voltage function
- **SINUSOID** Varies the voltage sinusoidally across the array.
 - **AMPLITUDE** The zero-to-peak amplitude of the sinusoidal voltage function.
 - **CYCLES** The number of sinusoidal cycles across the pixel array.
 - **VERTICAL** The DC-offset of the sinusoidal voltage function.
 - **PHASE** Horizontal shift of the sinusoidal voltage function.
- **RANDOM** Randomly calculates a value between the specified upper and lower limits for each pixel.

4.1.7 Pattern Adjustment

- **OFFSET**
 - **HORIZONTAL** Shifts the pixel pattern left or right. Pixels at the ends “wrap” as they are shifted.
 - **VERTICAL** Applies a DC offset to the array pattern.
 - **APPLY** Adjusts the pixel array by the specified vertical and horizontal amounts.
- **SCALE**
 - **MULTIPLIER** A factor by which each pixel will be scaled.
 - **APPLY** Rescales the pixel array.
- **NOISE**
 - **NEGATIVE** The maximum value that would be subtracted from each pixel.
 - **POSITIVE** The maximum value that would be added to each pixel.
- **APPLY** Adjusts each pixel by a random amount bounded by the Negative and Positive limits.

5. User Development with LabVIEW™ VI's Provided by Meadowlark Optics, Inc.

Several VI's are included in a library file on the PixelDRIVE 3000 CD. They can be found in <drive letter>:\LabVIEW\ directory. LabVIEW™ VI's that interface with the D3128 are:

- Meadowlark Hex SLM User Example.VI
- Meadowlark Linear SLM User Example.VI
- Meadowlark Hex SLM User VI's.LLB
 - Meadowlark Load Hex Array.VI
 - Meadowlark Load Linear Array.VI
 - Meadowlark USB Com.VI
 - Meadowlark USB Easy Close.VI
 - Meadowlark USB Easy Open.VI
 - Meadowlark USB Read Temperature.VI
 - Meadowlark USB Set Temperature.VI

The user development directory includes a LabVIEW™ library file containing fundamental VI's and examples that implement them in rudimentary programs that set the hexagonal and linear voltage arrays. The LabVIEW™ back panels of the hex and linear example VI's have been made accessible to our customers to facilitate independent development. Developers are encouraged to open and examine the example VI diagram screens. Please note that the LabVIEW™ development suite (version 6.1 or greater) from National Instruments is required to use the included VI's, and Meadowlark Optics, Inc. does not provide this development package with PixelDRIVE 3000. It is assumed that the customer has experience programming in LabVIEW™ and understands good programming practices. Meadowlark Optics, Inc. cannot offer customer support for LabVIEW™ application development. If a developed or modified LabVIEW™ application is to be distributed in any way, please contact Meadowlark Optics for licensing and copyright details.

6. Care and Maintenance of the SLM Optics

The D3128 Spatial Light Modulator is a precision instrument and should be treated accordingly. It is especially important to observe good optics laboratory practices with the optical head. Do not allow the optics components to become soiled, and avoid excessive unnecessary cleanings. If cleaning is required, the drop-and-swab method is recommended. Wear finger cots or gloves and use lint-free optics tissue. Laboratory-grade methanol is recommended, and then only in evaporative amounts (i.e., use one drop; do not “douse” the optics). Laboratory-grade acetone can be used only if deemed absolutely necessary, and again only in evaporative amounts. Never use water-based cleaning solutions, never use methyl ethyl ketone (MKE) or other solvents, never immerse the optical head or saturate the optics with solvent, and never scrub or brush the SLM optics.

7. Frequently Asked Questions

Q: The controller is not working.

A: Check that the power supply is plugged in, front panel switch is on and the green power light is steady. Check the status of the D3128 under Windows® Device Manager. Occasionally it helps to reboot the controller: turn off the controller, wait a few seconds, then turn it back on. Then click the RESET button on the PixelDRIVE 3000 user interface.

Q: Why might the SLM “pause” or “freeze” when I run very fast frame updates (frame durations ~10 ms)?

A: High-speed frame cycling can experience software conflicts with other USB devices, network activity, and other applications (e.g., anti-virus software). If the system hangs during high-speed frame cycling, it is recommended that the host PC be removed from any network, that all other applications be closed, and that any other peripheral devices (especially those connected to USB ports) be removed.

Q: Are there Apple, Linux, OS/2, or UNIX versions of PixelDRIVE 3000? Can I use PixelDRIVE 3000 on a PC running MS-DOS®, Windows® 3.1, Windows® 95, or Windows® NT?

A: No. PixelDRIVE 3000 runs under the 98SE, ME, 2000 and XP versions of Microsoft® Windows® only.

- Q:** Can I write a program in C, FORTRAN, or Pascal that will talk to the D3128?
- A:** Meadowlark Optics, Inc. presently supports only LabVIEW™ software development for the D3128. Future releases might include development resources for alternative programming platforms.
- Q:** What is the purpose of the SYNC and TRIGGER connectors on the front panel?
- A:** The TRIGGER connector generates an output pulse coinciding with any update to the pixel array. This signal can be used to synchronize external devices to the D2138. The SYNC connector is not presently active; it is reserved for future applications.
- Q:** What are valid (x, y) pixel indices for the hexagonal array?
- A:** Pixel indices must occur as (odd, odd) or (even, even) pairings. For example, (0, 0) and (1, 1) are valid pixel indices, but (0, 1) is invalid. Horizontal index boundaries are $-6 \leq x \leq 6$. Vertical index boundaries are $-12 \leq y \leq 12$.
- Q:** I calculated a frame of pixel values for the hexagonal array using a spreadsheet and a formula $f(x, y)$. When I loaded the frame into PixelDRIVE 3000, the function was distorted, appearing stretched vertically or horizontally. What happened?
- A:** The aspect ratio of the indexing convention (the x and y coordinates of the pixels) is $1:\sqrt{3}$, not 1:1. When calculating pixel values, use $f(x \cdot \sqrt{3}, y)$ or $f(x, y/\sqrt{3})$.
- Q:** What are the power-on default voltage and temperature values?
- A:** After powering on the D3128, the array will be driven to 10 volts for 500 ms, switched to 5 volts for 500 ms, then switched to zero volts. Upon completion of the power-on voltage cycle, the USB connection to the PC will be established. The temperature setpoint initializes to 35°C.
- Q:** What is the purpose of the “extra” pixel control in the hexagonal pixel array?
- A:** This controls the “test pixel” which is a large, uniformly-driven region of the SLM optic outside of the patterned hexagonal pixel array.

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Appendix A. Pixel Data File Formats

PixelDRIVE 3000 offers a feature for saving and loading pixel configurations as ASCII-text data files. The first row of a Pixel data file is a space-delimited header line that includes the type of SLM, PixelDRIVE 3000 software version number, D3128 firmware version number, number of frames, number of pixels, and the date and time the file was generated. When a pixel data file is opened with PixelDRIVE 3000, the SLM identifier must match the hardware configuration of the SLM (*e.g.*, “Hex” for the Hex SLM and “Linear” for the Linear SLM). The remainder of the file includes tab-delimited columns of pixel values that differ depending on the type of SLM (hexagonal or linear).

A.1 File Format for the Hexagonal Array SLM

The second row is tab-delimited and contains header characters x and y , followed by frame duration times (in seconds). The 128 remaining rows are tab-delimited and consist of x -pixel indices, y -pixel indices, and pixel values. The file format is illustrated in Fig. 10.

Each row must contain data for a unique pixel, *i.e.*, the (x, y) indices of each row must not be repeated in a different row. For hexagonal SLM data files, the order in which the pixels appear is not important (they will be sorted by the (x, y) coordinates when PixelDRIVE 3000 reads the file). Columns represent frames and must be tab-delimited, and the PixelDRIVE 3000 frame sequence order is determined by the order in which columns appear in the data file.

A voltage “surface” function $V(x, y)$ can be evaluated to produce pixel values. In calculating analytical functions, it should be noted that the pixel indexing convention results in a $\sqrt{3} : 1$ aspect ratio. In other words, in order to adapt an analytical function of x and y , the y variables appearing in the analytical form must be divided by $\sqrt{3}$ (or x variables must be multiplied by $\sqrt{3}$) to achieve proper symmetric rendering on the pixel array.

SLM Identifier	Software Version	Firmware Version	Number of Frames	Number of Pixels	Date and Time	
Hex	1.02	3.00	3	128	06/04/2004 23:25:00	
x		y				Frame Durations (sec)
0.000000	12.000000	1.000000	2.000000	3.000000		Pixel (0, 12) Values
0.000000	10.000000	1.000000	2.000000	3.000000		Pixel (0, 10) Values
0.000000	8.000000	1.000000	2.000000	3.000000		Pixel (0, 8) Values
⋮	⋮	⋮	⋮	⋮		
0.000000	-12.000000	1.000000	2.000000	3.000000		Pixel (0,-12) Values
12.000000	12.000000	1.000000	2.000000	3.000000		Test Pixel Values
Horizontal Pixel Indices	Vertical Pixel Indices	Frame 1 Pixel Values	Frame 2 Pixel Values	Frame 3 Pixel Values		

Figure 10. PixelDRIVE 3000 ASCII Data File Format (Hexagonal Array). One header row, one row of frame durations, and 128 rows of pixel data. Two columns of (x, y) coordinates, the remaining columns denote frames of pixel data.

A.2 File Format for the Linear Array SLM

The second row is tab-delimited and contains frame duration times (in seconds). The 128 remaining rows are tab-delimited and consist of pixel values. Pixel values are sorted in ascending pixel-order. Columns represent frames and must be tab-delimited, and the PixelDRIVE 3000 frame sequence order is determined by the order in which columns appear in the data file. The file format is illustrated in Fig. 11.

A voltage vs. x function $V(x)$ can be evaluated to produce pixel values. In generating a list of pixel voltages, voltage values must be sorted as x varies from 1 to 128.

SLM Identifier	Software Version	Firmware Version	Number of Frames	Number of Pixels	Date and Time
Linear	1.02	3.00	3	128	06/04/2004 23:58:00
0.100000	0.400000	0.350000			← Frame Durations (sec)
1.000000	2.000000	3.000000			← Pixel 1 Values
1.000000	2.000000	3.000000			← Pixel 2 Values
1.000000	2.000000	3.000000			← Pixel 3 Values
⋮	⋮	⋮			
1.000000	2.000000	3.000000			← Pixel 127 Values
1.000000	2.000000	3.000000			← Pixel 128 Values
Frame 1 Pixel Values	Frame 2 Pixel Values	Frame 3 Pixel Values			

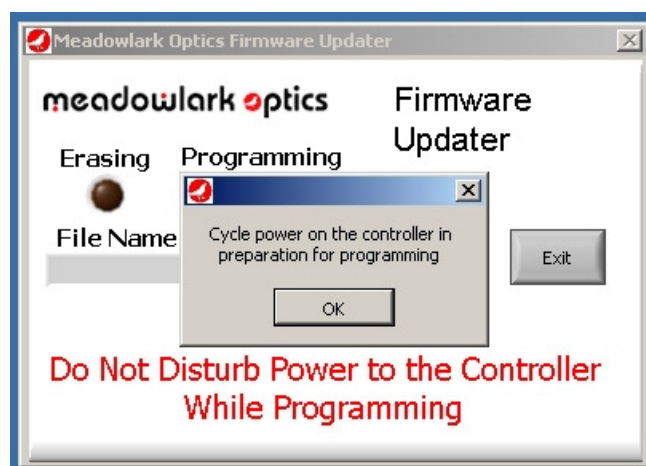
Figure 11. PixelDRIVE 3000 ASCII Data File Format (Linear Array). One header row, one row of frame durations, and 128 rows of pixel data. Each column denotes a frame of pixel data.

Appendix B: Firmware Updater

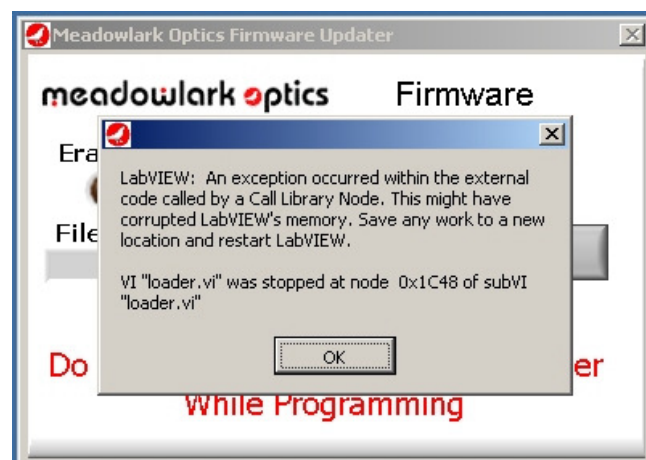
The D3128 internal firmware can be reprogrammed by the user when new versions are released by Meadowlark Optics. Update is accomplished by using the firmware updater program included on the PixelDRIVE CD. In order to use the firmware updater program the D3128 must be powered on and connected to an available USB port on the host computer.

Perform the following steps to reprogram the D3128 firmware:

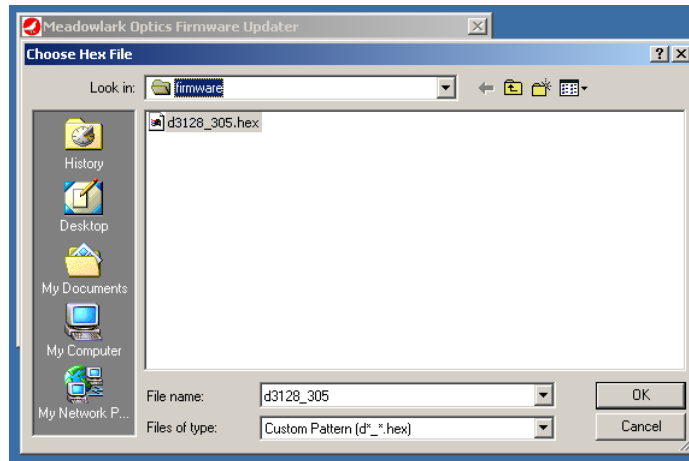
1. Install the firmware updater software on a PC running Microsoft® Windows® (98SE or later). Place the included CD in the CD-ROM drive, open the “Firmware updater” folder and double-click “setup.exe”.
2. Start the firmware updater software by clicking Start|Programs|Meadowlark Optics/Firmware updater. The following screen will appear:



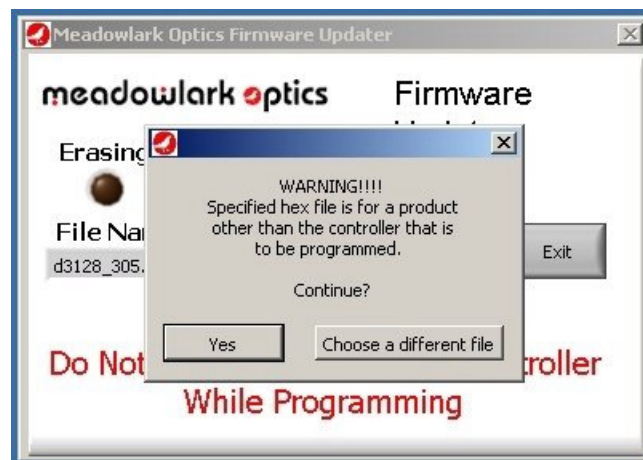
3. Cycle power on the D3128 controller to ensure the USB connection is properly made. After the front panel status LED is done flashing, wait at least 2 seconds before clicking OK. If the power is not cycled or the OK button is clicked too soon, the following error will be displayed. If this error appears, close the firmware updater program and re-run it.



4. The following screen will appear after the USB connection is made.



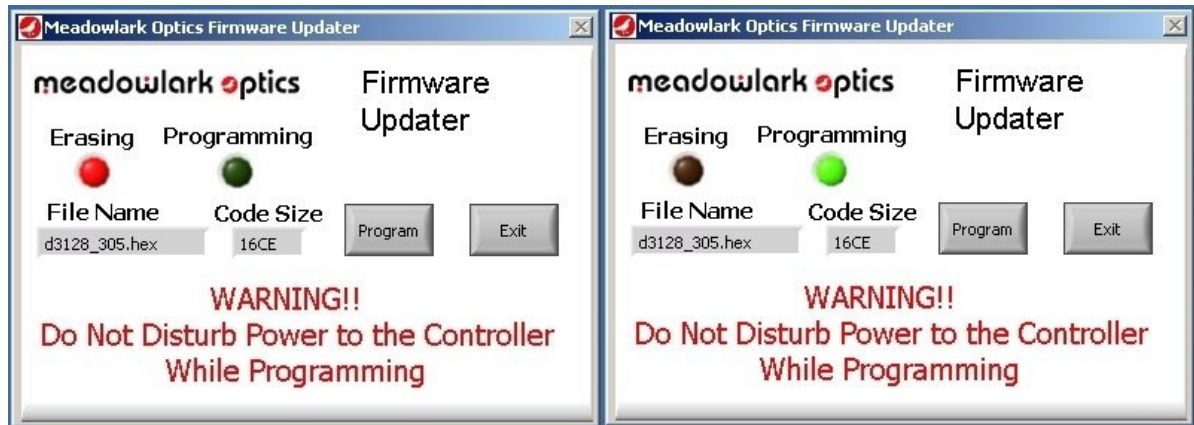
5. Choose the new hex file and click "OK". The program will check if the new firmware file is valid for the D3128, if not, the following error screen will appear. At this point the user may elect to choose a different file or go ahead and program the D3128 with the chosen file. Extreme caution should be exercised when deciding whether to program the D3128 with a file that may not be compatible. If there are questions about choosing the appropriate file please contact Meadowlark Optics at 303-833-4333.



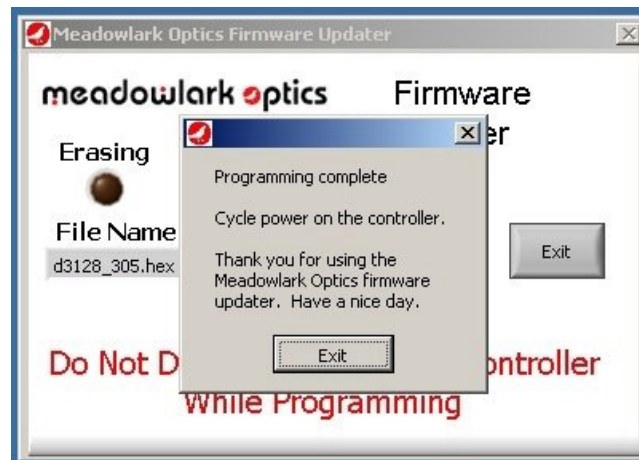
6. After the hex file is loaded and passes the validity tests, the ready screen appears as below (Code Size shows the size of the firmware code and is present only for troubleshooting). Click the Program button to reprogram the D3128 firmware. If a final check is desired before reprogramming firmware the Meadowlark Optics logo may be clicked to display a screen (shown below) showing the old and new firmware versions.



7. As the firmware is being erased and reprogrammed the status will be displayed as shown below. *DO NOT* disturb power to the D3128 while it is erasing or reprogramming, if memory is corrupted it will be required to return the unit to Meadowlark Optics for reprogramming.



8. After programming is complete the following screen appears. When the controller power is cycled the status light should flash a pattern corresponding to the version number of the new firmware. The new firmware version may also be determined by clicking the Meadowlark Optics logo in the upper left corner of PixelDRIVE.



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